(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 588 465 A1

# (12) EUROPEAN PATENT APPLICATION

(21) Application number : 93304068.5

(51) Int. Cl.[5] : H01Q 9/04

(22) Date of filing : 26.05.93

(30) Priority : 11.09.92 JP 243634/92

(43) Date of publication of application :
23.03.94 Bulletin 94/12

(84) Designated Contracting States :
DE FR GB IT

(71) Applicant : NGK INSULATORS, LTD.
2-56, Suda-cho, Mizuho-ku
Nagoya City Aichi Pref. (JP)

(72) Inventor : Nemoto, Hiroshi
126 Myoen-cho, Minami-ku
Nagoya 457 (JP)

(74) Representative : Paget, Hugh Charles Edward et al
MEWBURN ELLIS 2 Cursitor Street
London EC4A 1BQ (GB)

## (54) Ceramic dielectric for antennas.

(57) Disclosed is a ceramic dielectric material for an antenna, which is held between the conductor and ground-side electrodes of the antenna and has a water absorption of 1.0% or lower. This ceramic dielectric material is preferably alumina or a $CaTiO_3$-$MgTiO_3$ ceramic material. A microstrip antenna built up of this ceramic material can not only receive radio waves of a specific frequency, but can be improved in terms of reliability as well.

EP 0 588 465 A1

The present invention relates to a ceramic dielectric material for antennas. For instance, the invention is directed to a ceramic dielectric material that lends itself particularly well for microstrip antennas such as communications antennas mounted on moving bodies and to a microstrip antenna formed of this ceramic dielectric material as well.

Microstrip antennas generally designed to receive relatively feeble radio waves from communication satellites are used on moving bodies such as cars, ships and airplanes, because they are of less air resistance, are well attachable to them, are simple in construction, have attractive appearance, and so on.

Such microstrip antennas are generally constructed from a flat plate form of dielectric material having a ground-side conductor on one side and a radiation conductor on the other or opposite side. On the one side of the dielectric material there is located an amplifier for amplifying radio signals received or transmitted by the radiation conductor. The radiation conductor usually oscillates or receives quasi-micro or micro waves of about 1 to 10 GHz.

However, such a conventional microstrip antenna built up of a ceramic dielectric material, when exposed to raindrops or placed in a wet atmosphere, poses some problem. In other words, when moisture is adsorbed to the ceramic dielectric material, there is a considerable increase in its effective relative dielectric constant $\varepsilon$, because the relative dielectric constant of water $\varepsilon$ is 80.

It is here to be noted that microstrip antennas are typically characterized by having a much narrower frequency bandwidth of, e.g., 1.8 to 3.5%, at the frequency used, when compared with other antennas such as Yagi and parabola antennas. For this reason, when moisture is adsorbed to the ceramic dielectric material forming them, their substantial relative dielectric constants change largely, giving rise to a deviation of their resonant frequencies $f_{rc}$ from the predetermined frequency, as will be understood from the following equation:

$$f_{rc} = 1.841c/2\pi a\sqrt{\varepsilon}$$

where

$f_{rc}$ is the resonant frequency, Hz,
c is the velocity of light, $3 \times 10^{10}$ cm/s,
a is the effective diameter of the radiation (entrance) electrode, cm, and
$\varepsilon$ is the relative dielectric constant of the dielectric.

The central frequency received and oscillated by the antennas is therefore likely to vary due to some factors such as weather changes, rain, snow and humidity.

A ceramic material generally has open and closed pores. Especially in the case of some ceramic material having a large open pore rate, its relative dielectric constant increases, partly because of the skin effect, when water remains in the open pores, resulting in a variation of the oscillated or received central frequency mentioned above.

When a waterproof cover is mounted on an antenna built up of such ceramic material, its central frequency varies for reason of hygroscopicity incidental to a humidity change that occurs within the cover, and this is detrimental to its reliability. Another problem with plane antennas such as microstrip antennas is that their own operation becomes unstable due to hygroscopicity, particularly because their bandwidth is as narrow as 1 - 2 %.

In view of such problems as mentioned above, a primary object of the invention is to reduce the effect of water on a ceramic dielectric material. The invention consists in presetting the water absorption of a ceramic dielectric material at a given or lower value.

According to the invention, there is provided a ceramic dielectric material for an antenna, which is located between the ground-side and conductor electrodes of the antenna, said ceramic dielectric material being characterized by having a water absorption of 1.0% or below. It is noted that water absorption measurement is to be done according to JIS C2141.

Preferably, the ceramic dielectric material is alumina or the ceramic dielectric material is a ceramic material based on $CaTiO_3$-$MgTiO_3$.

The ceramic dielectric material for an antenna according to the invention makes some considerable contribution to improving the reliability of the antenna, because its water absorption is preset at a given or lower value, so that its relative dielectric constant and, hence, its central frequency can be kept stable.

The present invention will now be explained, more specifically but not exclusively, with reference to the accompanying drawing, in which:

FIGURE 1 is a schematic representation of a microstrip antenna.

The rudimentary construction of a microstrip antenna - to which the invention is applied - is schematically represented in FIGURE 1.

As illustrated, the microstrip antenna shown at 1 is made up of a flat plate form of ceramic dielectric material 2 that may be in disc, rectangular or other configuration. This material 2 is provided with a ground-side electrode 3 on the bottom and with a radiation electrode 4 on the top. The ground-side electrode 3 is grounded by

way of a conductor 5, and a conductor 6 coaxial with the conductor 5 is extended from the radiation electrode 4.

In order to reduce the pore ratio of the ceramic dielectric material 2 sufficiently and thereby reduce its water absorption, the feed is regulated to a given particle size distribution, and is then sintered at an elevated temperature for an extended time, using a pre-selected sintering aid. In the ensuing description, experimental examples carried out according to the invention will be explained at great length. Chemical compositions, etc., of the ceramic feeds used, and conditions for compacting (forming) and sintering them are shown in Tables 1, 2, 4 and 5. The water absorption of the obtained ceramic materials is then measured.

The ceramic dielectric materials with varying water absorption rates were used to fabricate various microstrip antennas, which were then subjected to water immersion testing.

Prior to this water immersion testing, whether or not the microstrip antennas under test could receive radio waves of such specific frequencies as mentioned above was confirmed. After this, they were immersed in water. Then, ten samples with a specific water absorption were investigated as to whether or not they could receive those radio waves.

The procedure of the water immersion testing involved immersing each sample in water of 25°C held at atmospheric temperature for 24 hours, then removing the sample from the water to clear water droplets of its surface, and finally allowing it to stand alone in the air with a relative humidity of 50% and a temperature of 25°C for 10 minutes. In the present disclosure, therefore, the wording "after immersion in water" is understood to refer to after the passing of 10 minutes during which the sample was allowed to stand alone in the air. The results using alumina are shown in Table 3 and those using $CaTiO_3$-$MgTiO_3$ are shown in Table 6.

All the materials of the present invention in Tables 3 and 6 showed a change in dielectric constant of less than 2%.

In the experiments, alumina and $CaTiO_3$-$MgTiO_3$ ceramics were used. It is understood, however, that the invention is in no sense limited to them; it is applicable to any ceramic material having a water absorption up to 1.0%. It is also noted that similar results as shown in Table 3 are obtainable even with ceramic materials that show a dielectric constant change of at most 2% between before and after the water immersion testing carried out in similar manner as mentioned above.

TABLE 1

| Feed Conditions | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chemical Composition (wt%) | | | | | Feeds | Feeds |
| | $Al_2O_3$ | MgO | CaO | $Y_2O_3$ | $SiO_2$ | Mean Particle Diameter | Particle Shape |
| Ex.1 | 84.5 | 3.0 | 2.7 | - | 9.8 | 2.4 | Rectangular, Scaly |
| Ex.2 | 84.5 | 3.0 | 2.7 | - | 9.8 | 2.2 | Rectangular, Scaly |
| Ex.3 | 84.5 | 3.0 | 2.7 | - | 9.8 | 2.0 | Rectangular, Scaly |
| Ex.4 | 95.0 | 0.8 | 0.9 | - | 3.3 | 3.0 | Rectangular, Scaly |
| Ex.5 | 95.0 | 0.8 | 0.9 | - | 3.3 | 2.5 | Rectangular, Scaly |
| Ex.6 | 95.0 | 0.8 | 0.9 | - | 3.3 | 2.2 | Rectangular, Scaly |
| Ex.7 | 99.0 | 0.7 | - | 0.2 | - | 1.7 | Uniform |
| Ex.8 | 99.2 | 0.6 | - | - | 0.2 | 1.6 | Uniform |
| Comp. Ex.1 | 84.5 | 3.0 | 2.7 | - | 9.8 | 2.0 | Rectangular, Scaly |
| Comp. Ex:2 | 95.0 | 0.8 | 0.9 | - | 3.3 | 1.5 | Rectangular, Scaly |
| Comp. Ex.3 | 99.0 | 0.7 | - | 0.2 | - | 1.5 | Uniform |

TABLE 2

| Compacting and Sintering Conditions | | | | |
|---|---|---|---|---|
| | Pre-Compacting Pressure ($kg/m^2$) | Sintering Conditions | | Water Absorption (%) |
| | | Temperature (°C) | Retention Time (h) | |
| Ex.1 | 1000 | 1500 | 2 | 0.1 |
| Ex.2 | 1000 | 1480 | 2 | 0.2 |
| Ex.3 | 1000 | 1430 | 2 | 1.0 |
| Ex.4 | 1300 | 1620 | 2 | 0.0 |
| Ex.5 | 1300 | 1570 | 2 | 0.2 |
| Ex.6 | 1300 | 1540 | 2 | 0.6 |
| Ex.7 | 1500 | 1600 | 2.5 | 0.0 |
| Ex.8 | 1500 | 1500 | 2.5 | 0.5 |
| Comp. Ex.1 | 1000 | 1420 | 2 | 1.2 |
| Comp. Ex.2 | 1300 | 1500 | 2 | 2.0 |
| Comp. Ex.3 | 1500 | 1450 | 2.5 | 5.0 |

TABLE 3

| Experimental Results ($Al_2O_3$) | | | |
|---|---|---|---|
| | Water Absorption (%) | Reception of Specific Frequencies (Ten samples) | |
| | | Before Immersion | After Immersion |
| Ex.1 | 0.1 | 10 | 10 |
| Ex.2 | 0.2 | 10 | 10 |
| Ex.3 | 1.0 | 10 | 10 |
| Ex.4 | 0.0 | 10 | 10 |
| Ex.5 | 0.2 | 10 | 10 |
| Ex.6 | 0.6 | 10 | 10 |
| Ex.7 | 0.0 | 10 | 10 |
| Ex.8 | 0.5 | 10 | 10 |
| Comp. Ex.1 | 1.2 | 10 | 8 |
| Comp. Ex.2 | 2.0 | 10 | 6 |
| Comp. Ex.3 | 5.0 | 10 | 5 |

TABLE 4

| Feed Conditions | | | | | | |
|---|---|---|---|---|---|---|
| | Chemical Composition (wt%) | | | | Feeds | Feeds |
| | $MgTiO_3$ | $CaTiO_3$ | $Fe_2O_3$ | $La_2O_3$ | Mean Particle Diameter (μm) | Particle Shape |
| Ex. 1 | 93.0 | 6.5 | 0.5 | - | 1.2 | Rectangular Scaly |
| Ex. 2 | 93.0 | 6.5 | 0.5 | - | 1.2 | Rectangular Scaly |
| Ex. 3 | 93.0 | 6.5 | 0.5 | - | 1.2 | Rectangular Scaly |
| Ex. 4 | 93.0 | 6.5 | 0.5 | - | 1.2 | Rectangular Scaly |
| Ex. 5 | 93.0 | 6.5 | - | 0.5 | 1.5 | Rectangular Scaly |
| Ex. 6 | 93.0 | 6.5 | - | 0.5 | 1.5 | Rectangular Scaly |
| Ex. 7 | 93.0 | 6.5 | - | 0.5 | 1.5 | Rectangular Scaly |
| Ex. 8 | 93.0 | 6.5 | - | 0.5 | 1.5 | Uniform |
| Comp. Ex. 1 | 93.0 | 6.5 | 0.5 | - | 1.2 | Rectangular Scaly |
| Comp. Ex. 2 | 93.0 | 6.5 | - | 0.5 | 1.5 | Rectangular Scaly |
| Comp. Ex. 3 | 93.0 | 6.5 | 0.5 | - | 1.2 | Uniform |

TABLE 5

| Compacting and Sintering Conditions | | | | |
|---|---|---|---|---|
| | Pre-Compacting Pressure ($kg/m^2$) | Sintering Conditions | | Water Absorption (%) |
| | | Temperature (°C) | Retention Time (hr.) | |
| Ex. 1 | 1000 | 1360 | 4 | 0.1 |
| Ex. 2 | 1000 | 1340 | 4 | 0.2 |
| Ex. 3 | 1000 | 1320 | 4 | 0.4 |
| Ex. 4 | 1000 | 1320 | 2 | 1.0 |
| Ex. 5 | 1000 | 1360 | 4 | 0.0 |
| Ex. 6 | 1000 | 1340 | 2 | 0.8 |
| Ex. 7 | 1000 | 1320 | 6 | 0.3 |
| Ex. 8 | 1000 | 1360 | 6 | 0.0 |
| Comp. Ex. 1 | 1000 | 1300 | 4 | 1.2 |
| Comp. Ex. 2 | 1000 | 1300 | 2 | 2.2 |
| Comp. Ex. 3 | 1000 | 1300 | 1 | 4.0 |

TABLE 6

| Experimental Results ($CaTiO_3$-$MgTiO_3$) | | | |
|---|---|---|---|
| | Water Absorption (%) | Reception of Specific Frequencies (Ten samples) | |
| | | Before Immersion | After Immersion |
| Ex.1 | 0.1 | 10 | 10 |
| Ex.2 | 0.2 | 10 | 10 |
| Ex.3 | 0.4 | 10 | 10 |
| Ex.4 | 1.0 | 10 | 10 |
| Ex.5 | 0.0 | 10 | 10 |
| Ex.6 | 0.8 | 10 | 10 |
| Ex.7 | 0.3 | 10 | 10 |
| Ex.8 | 0.0 | 10 | 10 |
| Comp. Ex.1 | 1.2 | 10 | 8 |
| Comp. Ex.2 | 2.2 | 10 | 5 |
| Comp. Ex.3 | 4.0 | 10 | 3 |

With the ceramic dielectric material for an antenna according to the invention, which has a specific water absorption, it is possible for the antenna to receive a specific frequency and be improved in terms of reliability, as already noted.

## Claims

1. A ceramic dielectric material for an antenna, which is held between the conductor and ground-side electrodes of the antenna and has a water absorption of 1.0% or lower.

2. A ceramic dielectric material for an antenna as recited in claim 1, which is used at a frequency lying in the range of 1 GHz to 10 GHz.

3. A ceramic dielectric material for an antenna as recited in claim 1 or 2, which is used in the open air or in a moist atmosphere.

4. A ceramic dielectric material for an antenna as recited in any of claims 1 to 3, which is used at a frequency lying in the range of 1 GHz to 10 GHz and in the open air or in a moist atmosphere.

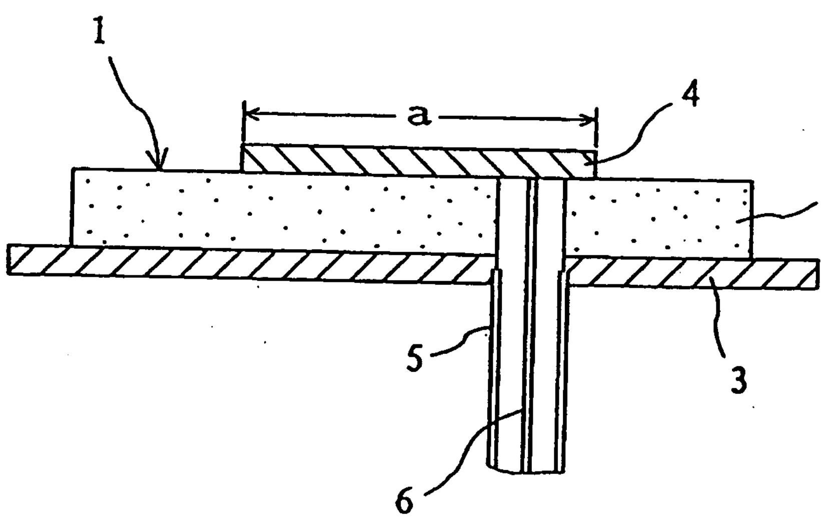
5. A ceramic dielectric material as recited in any one of claims 1 to 4, which is alumina.

6. A ceramic dielectric material as claimed in any one of claims 1 to 4, which is a $CaTiO_3$-$MgTiO_3$ ceramic material.

7. A ceramic dielectric material, which is held between the conductor and ground-side electrodes of the antenna and has a dielectric constant change of 2% or lower due to water absorption.

8. A microstrip antenna fabricated by using a ceramic dielectric material as claimed in any one of claims 1 to 7.

FIGURE 1



European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 93 30 4068

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.5) |
|---|---|---|---|
| A | IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION<br>vol. 29, no. 1 , January 1981 , NEW YORK US<br>pages 2 - 24<br>K.R. CARVER ET AL. 'Microstrip antenna technology'<br>* table 1 *<br>--- | 1,2,4,5, 8 | H01Q9/04 |
| A | H. JASIK 'Antenna engineering handbook'<br>1961 , MCGRAW-HILL , NEW YORK<br>* tables 35-2 *<br>--- | 1,2,4,7, 8 | |
| A | TOUTE L'ELECTRONIQUE<br>no. 416 , December 1976 , PARIS FR<br>pages 41 - 44<br>P. LEMEUNIER 'Pour les circuits imprimés << hyperfréquences >> : les polymères fluorés'<br>* page 43, right column, line 8 - line 13; figures 2,7 *<br>--- | 1,2,4,7, 8 | |
| | | | TECHNICAL FIELDS SEARCHED (Int.Cl.5) |
| A | IEE PROCEEDINGS B. ELECTRICAL POWER APPLICATIONS<br>vol. 106, no. 25 , January 1959 , STEVENAGE GB<br>pages 129 - 139<br>A.F. HARVEY 'Parallel-plate transmission systems for microwave frequencies'<br>* page 138, left column, line 1 - line 6; figure 17; table 1 *<br>--- | 1,2,4,7, 8 | H01Q<br>H01P |
| A | US-A-4 518 737 (TRAUT)<br>* column 1, line 18 - line 39 *<br>* column 2, line 36 - line 66 *<br>* column 6, line 26 - line 30 *<br>----- | 1,7 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 21 December 1993 | Den Otter, A |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)